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LONG TERM ACCLIMATIZATION TO HEAT

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Alterations in physiological response to heat induced in the human body by continued exposure to conditions of high temperature or to the combination of high temperature and high humidity have been investigated by many physiologists (1-10). The data available provide descriptions of the changes in skin and rectal temperature, pulse rate, sweat loss (7, 8, 9) and sweat composition (10), blood pressure (7, 9), and metabolism (4). These changes, occurring during relatively short term exposures to heat, establish the existence of a physiological adjustment which may be termed acclimatization. The data also indicate that, during this process of acclimatization, the comfort and efficiency of an individual increase (7, 8, 9). The major portion of this adjustment has been observed to occur within the first four or five days of exposure. However, physiological changes occurring during an extended exposure period have never been reported.

In the course of United States Army Quartermaster Corps investigations concerned with evaluation of the physiological heat load imposed by various uniforms, it has been possible to observe the reactions of seven healthy young men performing standard exercise under conditions of high temperature and high humidity for a period of twenty-five weeks. Data presented in this communication reveal the reactions during this long term exposure to these ambient conditions.

METHODS. All experiments were conducted between November first and April twenty-fourth in the Jungle Chamber of the Climatic Research Laboratory, Lawrence, Mass. Throughout the study, the temperature of the room was controlled at 90°F., dry bulb, and 86°F., wet bulb (relative humidity) 85 per cent). Temperatures of walls, ceiling, and floor were maintained at the existing dry bulb temperature by circulation of hot water through radiant panels. Daily and day-to-day variations rarely exceeded 1°F., dry bulb, and 0.75°F., wet bulb. Variations in relative humidity were less than ± 2 per cent. The wind velocity in all studies was 1.5 mph.

Gross physical characteristics of the subjects (seven young, healthy, white soldiers) are presented in table 1. At the initiation of the study, the subjects were physically conditioned by two weeks of field exercise. Thereafter, they were exposed to the designated ambient conditions during a period of one month, each subject spending at least three hours a day, five days a week, in the Jungle Chamber. Of the three hours, at least one was spent in exercise.

¹ Reprints of this paper may be obtained from the Research and Development Branch, Office of The Quartermaster General, Washington 25, D. C.

Collection of the data presented in this report was initiated at the conclusion of this preliminary one-month exposure period. They comprise the results of thirty control experiments conducted during an investigation of the comparative physiological heat loads imposed by uniforms. Throughout the investigation, a control experiment was usually conducted at least once a week, and sometimes more often. These experiments followed a rigidly standardized routine which may be briefly described as follows:

1. After entering the chamber, each subject spent the first hour at rest.
2. Upon completion of this initial hour of adjustment, the subject was weighed with an accuracy of ± 5 grams, his rectal temperature was determined within the nearest 0.1°F . by means of a clinical thermometer, and his pulse measured by auscultation. Immediately thereafter, the exercise started. Each subject walked for one hour on a horizontal treadmill at the standard rate of 3.5 mph. No rests were permitted and no measurements were recorded during this period. Drinking water was prohibited.

TABLE 1
Physical characteristics of subjects

SUBJECT	HEIGHT	WEIGHT	AREA	HABITUS
	<i>inches</i>	<i>pounds</i>	<i>M.²</i>	
R. B.....	68	138	1.75	Asthenic
J. E.....	70.5	167	1.95	Asthenic
A. H.....	70.5	167	1.95	Sthenic
J. P.....	73	161	1.98	Asthenic
C. T.....	71	180	2.03	Sthenic
A. W.....	69	185	2.02	Sthenic
J. Z.....	68.5	164	1.89	Sthenic

3. As soon as the subject stepped off the treadmill, his pulse (taken for 30 seconds and multiplied by 2) and rectal temperature were determined. Upon completion of these measurements, he was wiped dry of all perspiration and weighed.

4. After weighing, the activity of the subject was unrestricted, but he was required to remain in the experimental chamber for an additional hour.

Two subjects walked on the treadmill simultaneously. All wore similar clothing, namely, cotton shorts, light wool socks, and jungle boots. This gear was standard throughout the exposure period. No attempt was made to have the subjects on the treadmill at the same time each day. Precautions were taken to insure that a high level of health was maintained. Weights were recorded daily and urine chlorides checked periodically to be certain that no dehydration or salt deficit developed.

RESULTS. The data obtained illustrate the physiological response of seven healthy males to prolonged exposure in ambient conditions of high temperature and humidity. Mean values and standard deviations for the rectal temperatures and pulse rates of each subject are presented in table 2. It will be seen that

these values were reproducible (within the limits described) from day to day over a long period and that no definite trend occurred. However, during this

TABLE 2
Summary of data on rectal temperature and pulse rate

SUBJECT	RECTAL TEMPERATURE		PULSE RATE	
	Mean	Standard deviation	Mean	Standard deviation
	^{°F.}		<i>per minute</i>	
R. B.....	100.64	0.32	126.8	10.3
I. E.....	100.56	0.24	130.5	10.1
A. H.....	99.87	0.23	124.8	10.0
J. P.....	100.91	0.31	109.2	9.5
C. T.....	100.15	0.23	108.2	9.1
A. W.....	100.23	0.22	107.8	8.2
J. Z.....	100.66	0.30	129.3	11.1

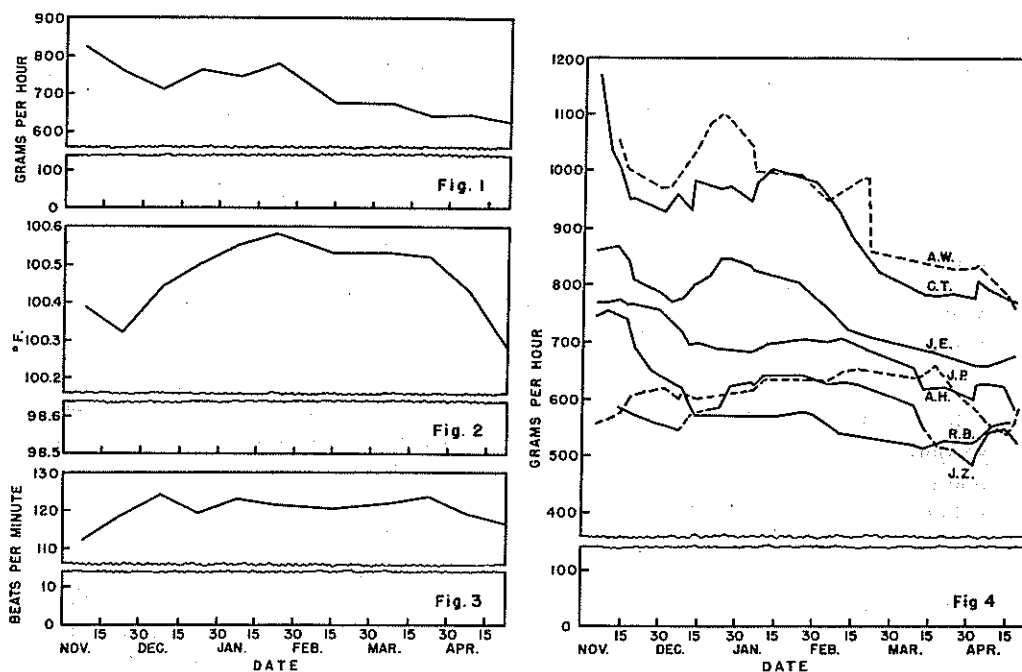


Fig. 1. Mean weight loss—5 exposure moving average.

Fig. 2. Mean rectal temperature—5 exposure moving average.

Fig. 3. Mean pulse rate—5 exposure moving average.

Fig. 4. Individual values for weight loss—5 exposure moving average (values in grams).

six-month period, there appeared to be a slight but definitely downward trend in weight loss.² This trend is demonstrated by a comparison of figures 1, 2, and 3,

² Weight loss and sweat loss are used interchangeably. Decrease in weight due to loss of water through respiratory tract and loss of carbon dioxide is considered constant and negligible.

illustrating, respectively, the average weight loss, rectal temperature, and pulse rate. In order to smooth the curves so that the results may be easily interpreted, each point in these graphs represents a five-exposure moving average.

The results presented in figure 1 reveal a decline in the mean value for weight loss. At the initiation of the experimental period, the mean weight loss was 825 grams per hour. At the conclusion, this value had declined to 640 grams per hour. A detailed presentation of these data is provided in figure 4. In this figure, the five-exposure moving average has been calculated for each of the seven subjects. Five exhibit a definite decline in sweat production. Two, J. P. and J. Z., show no constant deviation throughout the period. Nothing unusual was observed relating to the body habitus, previous experience, or ease of work performance which distinguished these two groups. However, the weight losses of J. P. and J. Z. were initially lower than the comparative values of other subjects similar in size and body build.

Five-exposure moving averages for rectal temperatures and pulse rates (figs. 2 and 3) indicate no significant variation in either direction. The dissociation between weight loss and these values is striking. Although the weight loss declined, the rectal temperature and pulse rates remained unaltered.

DISCUSSION. Previous studies of acclimatization emphasize the salient changes in physiological adjustment during the first four or five days of exposure to hot environment. Numerous investigators have stated that, at the conclusion of such a five-day period, a subject is able to complete a given work period with lower rectal temperature, pulse rate, skin temperature, and more stable blood pressure (7, 8, 9). None of these investigators, however, has reported data extending over a period as long as the term of the experiment described in this communication. Since no striking improvement had appeared after the fifth day, it probably had been assumed that acclimatization was complete, that a stable state had been attained.

It could be presumed, therefore, that a similar condition existed at the initiation of this experiment, the subjects having been exposed to a hot environment for one month before collection of data. During the experiment, exposures were made almost daily for a period of 6 months and physiological data were periodically collected. The results demonstrate that in a majority of subjects, except for minor fluctuations, there was an over-all decline in sweat rate during continued exposure to the ambient conditions of this experiment. This phenomenon was more marked in the two subjects with high initial sweat rates. Two subjects with low initial sweat rates showed no change. The range between the individual rates was greater at the beginning of the study than at the end, i.e., there was a tendency to approach a common basal value for sweat production. Even at the termination of the six-month period there was no evidence that the progressive decline had ceased. Thus, in a majority of subjects, acclimatization, as evidenced by decrease in sweat rates, is a continuous process.

It must also be noted that no downward trend in the rectal temperature and pulse rate accompanied the sweat rate. While the data demonstrate that the adjustment to high temperature and high humidity continues over an

extended period, they do not indicate that there was a significant increase in working ability. The subjects were more efficient and their adjustment more satisfactory only in that they did not produce as much sweat. However, under the conditions of this experiment an excess of perspiration is produced. The reduction, therefore, is only of importance because it effects a slight economy in the salt and water requirements of the subjects.

The data also indicate that there is no constant relationship between rectal temperature and sweat rate—the latter values dropped while the former remained constant. The progressive decline in sweat rate may account for the observation that persons who have undergone prolonged exposure to high temperature do not produce as much sweat as those recently exposed (11).

SUMMARY

This report presents data relating to the physiological response of seven healthy males to daily exposure in conditions of high temperature and humidity during an extended period. The subjects, after being acclimatized for one month, were exposed to these ambient conditions for six months. The results indicate that there is no trend in either the pulse rates or rectal temperatures. However, five of the seven subjects exhibited a decline in sweat rate throughout the experimental period.

The implications of these observations are briefly considered.

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